ISSN 0704-3716

Canadian Translation of Fisheries and Aquatic Sciences

No. 5256

To the knowledge of the Vasodentine

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Original title: Zur kenntnis des Vasodentins

In: Zeitschrift fur Mikroskopisch - Anatomische Forschung 48: 461-477, 1940

Original language: German

Available from:
Canada Institute for Scientific and Technical Information
National Research Council
Ottawa, Ontario, Canada K1A 0S2

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LIBRARY IDENTIFICATION – FICHE SIGNALÉTIQUE

Translated from - Traduction de	Into - En
German	English

Author - Auteur

Kohlenberger, Heinrich

Title in English or French - Titre anglais ou français

To the Knowledge of the Vasodentine.

Title in foreign language (Transliterate foreign characters)
Titre en langue étrangère (Transcrire en caractères romains)

Zur Kenntnis des Vasodentins..

Reference in foreign language (Name of book or publication) in full, transliterate foreign characters.
Référence en langue étrangère (Nom du livre ou publication), au complet, transcrire en caractères romains.

not shown

Reference in English or French - Référence en anglais ou français

not shown

Publisher - Éditeur	DATE OF PUBLICATION / DATE DE PUBLICATION			Page Numbers in original / Numéros des pages dans l'original
not shown	Year / Année	Volume	Issue No. / Numéro	461–477
Place of Publication / Lieu de publication				Number of typed pages / Nombre de pages dactylographiées
not shown	1940	48		25

Requesting Department / Ministère-Client: DFO

Translation Bureau No. / Notre dossier nº: 2537230

Branch or Division / Direction ou Division: IPB

Translator (Initials) / Traducteur (Initiales): AB

Person requesting / Demandé par: N. Johnson

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Your Number / Votre dossier nº:

Date of Request / Date de la demande: 86-08-07

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2537230	German	AB	OCT 2 9 1986

V.48, 1940.

From the Institute of Anatomy of the University of Marburg a.d. Lahn (Anatomische Anstalt der Universität Marburg a.d. Lahn), Director: Prof. Dr. Becher.

To the Knowledge of the Vasodentine.[1)]

By Heinrich Kohlenberger.

With 12 text figures.

(send in: May 12, 1940).

Introduction.

Since 1937 JACOBSHAGEN and a number of students have carried out comprehensive new investigations of the dentition and teeth of lower vertebrates. Their aim was to reconstruct the comparative dental anatomy. This reconstruction was to be carried out with constant consideration of the findings gained from the original phylogenetic material, i.e. the placoid organs of the selachian skin. It furthermore involved the analyzation of the results of the investigations by JACOBSHAGEN and his student E. HESSEL (1923) which had hitherto been ignored. As well, the reconstruction was to take into account the changed

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situation resulting for the comparative dental anatomy from JACOBSHAGEN's statements concerning the indefensibility of Oskar HERTWIG's theory; this theory, which had been accepted unchallenged from 1874 to 1923, advocated the derivation of the vertebrate dental cement from an alledged "scale cement" of the placoid organs.

The questions: Where in the vertebrate spectrum does dental cement occur for the first time? - In what form does it occur? - Where does it originate? - demand new investigations today.

JACOBSHAGEN had in 1923 already initiated this reconstruction of the comparative anatomy of vertebrate teeth which he essentially based also on the investigations of his student H. FROEHLICH. He attempted to establish the fundamental characteristics of the dentine of the placoid organs in the selachian skin and of the selachian teeth. p.462

Neither the tangential dentinal fibrils embedded in an organic cement substance impregnated with calcium salts, nor the additionally penetrating plasmatic cell processes of the scleroblasts - they are responsible for the metabolism of the matrix - conclusively characterize the dentine as compared with the other mesodermal hard tissue of the vertebrates, the bone.

As a matter of fact, this is dependend on a third condition: the establishment of a relationship, at least ontogenetically, between the dentine and the dental pulp.

On the basis of this relationship to the pulp, JACOBSHAGEN differentiates two types of dentine in selachians:

1. Mantle dentine.

2. Trabecular dentine.

Mantle dentine is produced by the superficial odontoblast layer surrounding the dental pulp in the form of an envelope. The oldest and most common envelope is a hollow dentine cone surrounding the apical part of the dental pulp. The basal pulp surface lacks a hard substance layer. However, the basal side of the dental pulp, i.e. the border surface between it and the underlying connective tissue, is frequently covered by an odontoblast layer which forms a "cover plate" of mantle dentine. The dental pulp in this case is therefore completely surrounded by mantle dentine.

The trabecular dentine, where it occurs, always forms on the inside of the mantle dentine. It is thus always a secondary type of dentine. During its development, parts of the odontoblast layer on the pulp surface grow into the depth of the dental pulp and in this way form dentine trabeculae which are naturally penetrated all around by axially oriented odontoblast processes. The dentine trabeculae usually form a three-dimensional intra-pulpal framework which contributes to the supporting function of the mantle dentine when the teeth are in use. This framework occurs in mantle-dentine teeth with or without a cover plate at the base of the dental pulp. When the dentine trabeculae grow in thickness it is at the expense of the dental pulp which becomes narrower locally. Already in the specialized placoid denticles of the selachian skin - i.e. in the rostral marginal teeth of the so-called saw of the sawfish (Pristis) - this development may go so far that, in the interspaces of the trabecular dentine framework, the blood capillaries of the dental pulp are surrounded only by traces of pulp tissue.

I was assigned the task by Prof. JACOBSHAGEN to establish:

1. Whether the so-called vasodentine, particularly that in the gadid family among the teleosts, is a dentine at all in JACOBS - HAGEN's sense as described above.

2. If this is found to be the case, to establish whether the vasodentine belongs to the mantle or to the trabecular dentine and to define its characteristics.

3. To study the morphological relationship of the vasodentine with KAMPSCHULTE's types of the other teleost teeth.

In Prof. JACOBSHAGEN's view, an original investigation of the vasodentine, particularly of the gadid vasodentine, was of decisive value to put an end to the "dentine chaos" in the previous literature. This was naturally a deciding factor also in the formulation of this paper.

The Material and its Analyzation. p.463

On JACOBSHAGEN's instigation, Franz KAMPSCHULTE had already investigated polished and sectioned preparations of gadid teeth. It was found, however, that his material of mature gadid teeth was unsuitably preserved and that in order to clarify the pending questions it would be essential to also include developmental stages in the study. Despite the war, Prof.Dr. JACOBSHAGEN, thanks to the cooperation of the director of the Institute of Anatomy (Anatomisches Institut), Prof.Dr. Becher, from the National Institute of Biology (Staatliche Biologische Anstalt) of Helgoland, obtained Gadus Morrhua heads fixated in formolized sea-water ; and furthermore an entire series of developmental stages of

Gadus merlangus also fixated in formolized seawater - incidentally, some of these specimens were excellently fixated - which he handed over to me for detailed investigations. From Helgoland also originated the large Anarrhichas lupus which I studied later. I prepared polished specimens as well as sections of the teeth of the mature animals. Of the developmental stages I was able only to prepare sections on account of the softness of the material. It is appropriate to briefly discuss the preparation methods.

The preparation of polished sections was very difficult at first because of the small size of the teeth, which KAMPSCHULTE already found to be a problem as he described in his paper. His method was to dry grind his specimens on carborundum which, to save time, I modified as follows: I first ground on the carborundum stone by means of emery and water, then continued the process on a smooth Arkansas stone with water only and later with alcohol which took care of the removal of adhering grinding particles etc. This was followed by polishing with alcohol on a glass plate which produced quite adequate polished preparations.

The sections were decalcified with 5% Trichloroacetic Acid and embedded according to the Celloidin method since the sections obtained with the freezing microtome were of poor quality. I found Hematoxylin staining after WEIGERT followed by differentiation in van-GIESON-solution or simple Picric Acid the most suitable method for my preparations. In the course of the investigations it proved useful to examine also the teeth of other fishes belonging to the teleost group. Prof. JACOBS-HAGEN made specimens of Anarrhichas lupus, Acanthurus nigrofuscus and Blennius available.

The Vasodentine.

Vasodentine, in the sense applied by this author, was discovered by RETZIUS 1835 and described in some detail 1878 by Charles S. TOMES in gadids. It was investigated also by RÖSE 1897.

I. The Vasodentine in the Mature Gadus morrhua.

My investigation started therefore also with a gadid, i.e. the codfish (G. morrhua).

Fig.1 shows the polished sagittal section of a lower jaw of G. morrhua. On the lingually sloped surface of the lower jaw occurs an obliquely backward inclined bony base on top of which is anchored the coniform, slightly recurvate tooth by means of a syndesmosis. The base of the tooth is seen to form an inner circular bulge which toward the periphery is sitting concavely on the bony base. The axial pulp cavity reaches up into the apex of the tooth, in our specimen it is occupied by dried-up, fissured pulp. It is surrounded by the hollow dentine cone in which two different zones can be distinguished. The inner, wider zone is permeated by black vascular tubules which begin and end in the pulp and send off convex loops toward the periphery. These may be simple or complexly ramified and are also connected together peripherally, which is particularly evident in the apical parts. The connections become scarcer toward the base. Peripherally of this vascular dentine zone follows an avascular dentine layer. Its thickness reaches basally a third, apically however at least two thirds of the entire dentine layer. This fundamental differentiation of the dentine layer in a central vascular and a peripheral avascular zone applies to all gadids with the exception of Lotella.

p.464

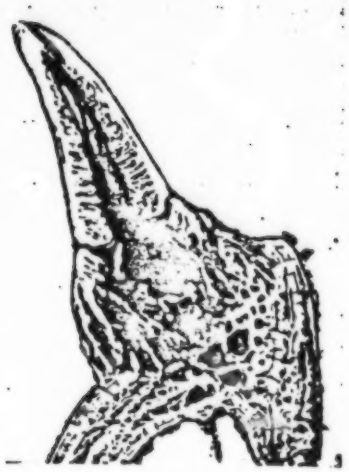

Fig.1: Gadus morrhua. Polished sagittal section of a tooth of the lower jaw.

Fig.1 does not quite display that degree of complexity of the vascular ramifications described by RÖSE in Merlucius and by TOMES in the hake and which, according to the latter author, also exists in Molva. Slightly less complicated, according to TOMES, is the vascular apparatus in Brosmius and Raniceps. In other gadid species - Merlangus pollachius, Gadus minutus and Gadus luscus - TOMES found simpler vascular loops, which at best were connected together near the apex. He found still simpler, i.e. unconnected vascular loops in Gadus aeglefinus, Lota, Merlangus carbonarius, Uraleptus, Phycis and Motella, while in Lotella he saw no such vascular loops at all.

Returning to Fig.1: Attention is drawn to the small enamel cap which merely covers the tip. p.465

A comparison of a median-sagittal section through a decalcified upper jaw tooth as control with fig.1 shows the following:

The basal end of the tooth on the lingual side gives off tangential dentinal fibrils along its entire width. They form a fibrillar mass and pervade the space between tooth and underlying bony base and merge with the fibrils of the latter. The mentioned dentinal fibrils come from the dentine as well as from the predentine situated near the pulp. In the space between tooth and bony base do not occur any connective tissue nuclei, but large numbers of them are found in the lingual-most area.

The syndesmosis on the labial side in the area of the central basal bulge of the tooth is of the same appearance, connective tissue nuclei are lacking here as well. However, underneath the peripheral concave seam of the tooth, the fibrillar strands are disrupted and a nucleus-rich ligament connection is seen only lingual-most between tooth and base.

A further remarkable feature is the behavior of the tooth toward the epithelium of the mouth cavity. The epithelium reaches anteriorly and posteriorly pocketlike down to the syndesmosis. It does not cover the bony base therefore.

The pulp surface is of a different appearance. The teeth that I examined were usually not quite fully grown yet. There occurred a closely packed layer of odontoblasts which increases in height beginning in the region of the syndesmosis in apical direction to approximately the tooth base. This layer extends in similar arrangement, except for interruptions at certain intervals by vasodentine tubules passing through, as far as the apical half of the tooth. Here the odontoblasts become flatter and are soon indistinguishable from flat connective tissue cells. I tried hard to trace odontoblast processes into the

dentine. This was most successful with preparations overdyed with WEIGERT's Hematoxylin and then differentiated with Picric Acid. Here, in the basal part I could see odontoblasts invade the predentine and shortly after divide dichotomously, but they advanced no further than the middle of this layer at the most. (Unfortunately, this could not be recorded on film). I did not find any odontoblasts in the dentine. Approximately in the middle of the tooth, with the predentine having become quite narrow and the odontoblasts shortened, I was able to trace the odontoblast processes through the entire predentine. Contrastingly, I did not see the flat cells of the apical part give off any odontoblast processes. - I am omitting a discussion of the pulp structure.

TOMES already remarked on the peculiar behavior of the odontoblasts at the vasodentine and spoke of a typical deficiency of odontoblast processes as well as dentinal tubules. Our figure does not show any dentinal tubules either. But RÖSE depicted dentinal tubules in the peripheral zone in the cross section of a lower jaw tooth of a young haddock. - I also observed in a polished cross section of a lower jaw tooth of the cod (fig.2) peripherally a fine, radial, rather regular, longitudinal striation which may indeed represent vestigial dentinal tubules. I believe to have seen occasional traces of dentinal tubules also otherwise here and there. p.466

To sum up: It has now been established that the vasodentine of Gadus lacks normal dentinal tubules which contain odontoblast processes, and that only meagre traces of them are found in immature parts of the tooth near the pulp.

According to my observations, the capillary tubules, which are connected with the rich vascular system of the dental pulp (see also p.467

fig.5), exclusively contain branched or unbranched loops of blood capillaries, as shown in fig.3 of the tip of an already highly developed tooth of a 14.5 cm long whiting. They apparently do not contain any parts of the dental pulp or nerves.

Fig.2: Gadus morrhua. Detail from a polished cross section of a tooth. PD Peripheral dentine; BlK Blood capillary tubules; PH Pulp cavity.

Fig.3: Merlangus merlangus, 14.5 cm long. From a longitudinal section of the tip of the tooth. BlK Blood capillary in the mantle dentine.

Therefore, the vasodentine of the gadids is distinguished from normal dentine by a different mode of metabolism. The blood capillary loops pervading the dentine have directly taken over the function of the dentine metabolism, supplanting the odontoblasts in their ancient role as carriers of the metabolism. A further test showed that the dentine of Gadus morrhua as compared to other teleosts is characterized by low flexibility and great hardness. Finally, it was established that these teeth belong to KAMPSCHULTE's Type I since they apparently possess a true mantle dentine and lack a basal cover plate and trabecular dentine.

II. From the Ontogeny of the Gadus Teeth.

Fig.4 shows a longitudinal section through a young replacement tooth bud of a 14.5 cm long whiting. The deeply embedded epithelial enamel organ consists of a peripheral cubical and a central high-cylindrical enamel epithelium. The latter is already seen to give off short enamel fibers toward the dentine. The surface of the daggerlike dental papilla is covered by odontoblasts which merge basally with the connective tissue of the dental sac. The latter completely envelops the enamel organ. At this point a dentine layer of considerable thickness has been laid down. It advances and covers the dental pulp; in investigations with high magnification, odontoblast processes can be seen, particularly basally, to invade the dentine where I was unable, however, to trace their further course.

On the basis of its tissue, the tip of the future vasodentine tooth of the gadids thus represents mantle dentine which already at this early stage is marked by the peculiar shortness of its odontoblast processes.

However, there are no traces yet of a vascular system in the dentine in fig.4. - From the comparative-anatomical viewpoint, this tooth germ stage would also belong to KAMPSCHULTE's Type I of teleost teeth.

Fig.5 shows the sagittal section of a lower jaw tooth of a 14.5 cm long whiting. p.468

The young tooth rides on its bony base anchored to it by a syndesmosis. Vestiges of the epithelial enamel organ reach from above down to the bony base (similarly as in the mature animals therefore).

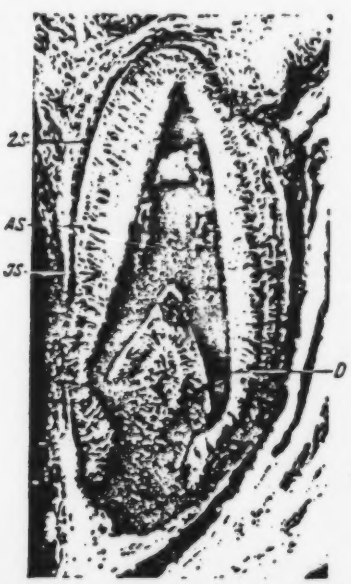

Fig.4: Merlangus merlangus. 14.5 cm. Longitudinal section of a replacement tooth bud. ZS Dental sac; AS Peripheral enamel epithelium; JS Central enamel epithelium; D Dentine.

The pulp fills the interior of the tooth, but it extends much further downward than the tooth and occupies also the interior of the bony base with its mass.

Thick strands of blood capillaries push upward through the dental pulp axis and give off branches toward the periphery.

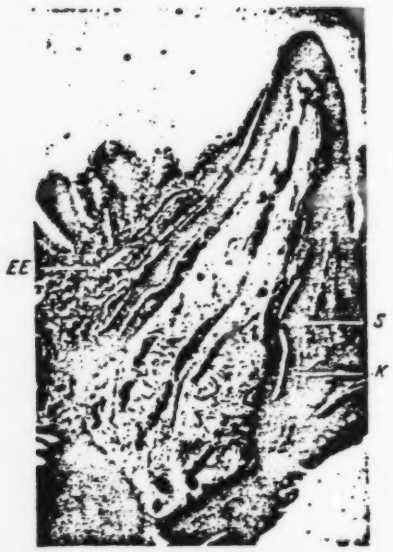

Fig.5: Merlangus merlangus, 14.5 cm long. Longitudinal section of a tooth bud. EE End of epithelial depression. S Syndesmosis; K Bony base.

The periphery is covered by an odontoblast layer, the cells of which are low apically but become increasingly higher further down. Contrary to the situation in the mature or nearly mature tooth, here this odontoblast layer does not end at the level of the syndesmosis of the tooth but reaches down almost to the base of the pulp cavity. The bony base is covered also on the outside by cells which send short processes into the base. They are osteocytes. A closer look at the behavior of the odontoblasts in the area of the tooth reveals on the left side odontoblast processes frequently invading the dentine. But the remarkable feature of fig.5 is that, at the tooth base, the odontoblasts with no apparent modification carry on as osteoblasts of the bony base. I was unable with this preparation as well to follow the odontoblast processes deeper into the dentine. They seem to end very early.

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Fig.5 already shows the presence of blood capillaries in the dentine and vessels which are about to invade this layer. Thus on the right, the odontoblast layer is disrupted closely above the tooth base and, as can be seen more clearly in the magnified detail in fig.6, capillary loops are already pervading the central part of the dentine. Above these areas the invasion of odontoblast processes into the dentine is again occasionally recognizable. The presence of capillary loops in the dentine itself has already been established, as mentioned above, in fig.3 of the tip of a tooth from the same fish.

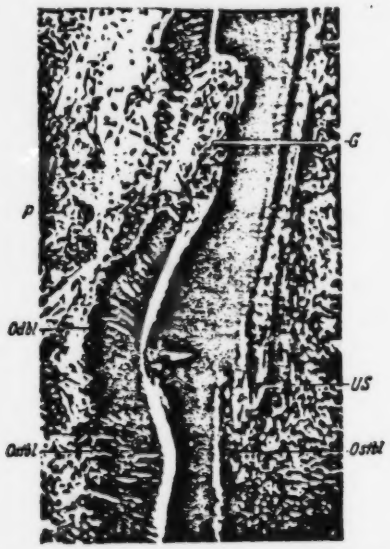

Fig.6: Detail from fig.5, more highly magnified. P Dental pulp; Odbl Odontoblasts; G Vessel; US Lower end of epithelial sheath; Ostbl Osteoblasts.

The tooth development of the 14.5 cm long animal therefore shows that the vasodentine represents a further developed mantle dentine which, combined with a larger increase in thickness, is penetrated by pulpal vessels. Very short odontoblast processes are seen here also,

but in Gadus they apparently never play an important part in the dentine nutrition; on the other hand, they remain evident in shortened form during the development of the dentine. It seems justified on the one hand to categorize the vasodentine under the term "mantle dentine"; p.470 on the other hand, there cannot be any doubt as to its real dentine character.

I take the liberty here to make some general comments. This tooth development differs from the normal situation. When, during the ontogenesis of the mammal tooth, the development of the root takes place, then the edge of the epithelial enamel organ pushes as epithelial sheath as far downward as the dental root later on. Interiorly however, the odontoblast mantle of the dental pulp and also the pulp itself follow this downward migration of the epithelial enamel organ. - In Merlangus the situation is entirely different: The enamel organ ends at the syndesmosis, i.e. at the base of the tooth. But the pulp pushes far beyond this point into the depth toward the jaw bone, followed by its odontoblast-covered surface. In the depth it forms a cell layer whose elements do not differ externally at all from odontoblasts. Therefore, the conception which ascribes the form development in the ontogenesis of the teeth exclusively to epithelial growth processes, cannot be correct. It is surely remarkable when the elements adjacent to the bony base rudiment appear to be continuous with the odontoblasts, while the cells applied to its outer side (as is seen in fig.6) are flatter and of only slightly different shape.

The bony trabeculae do not contain any osteocytes yet. However, they certainly occur in the fully grown fish, indeed also in that area of the lingual side immediately under the syndesmosis, which

(fig.1) distinctly shows three capillary tubules coming from the pulp, as well as in the overlying vasodentine layer.

Fig.7: Anarrhichas lupus. Position of the large vasodentine teeth.

Thus Gadus displays various similarities between odontoblasts and osteoblasts, and between dentine and bone, but without loss of border lines.

III. The Vasodentine of Anarrhichas lupus. p.471

The dentition of the wolffish has long been known for its massive and peculiarly shaped teeth.

Fig.7 shows the coniform grasping teeth of the anterior mouth region in their opposite position.

Fig.8 represents the dorsal dentition. A group of premaxillary conical teeth, a medial group of seven domed vomer teeth and lateral groups of low, coniform palatine teeth can be distinguished. A large number of mucosa papillae are recognizable in the spaces between these teeth.

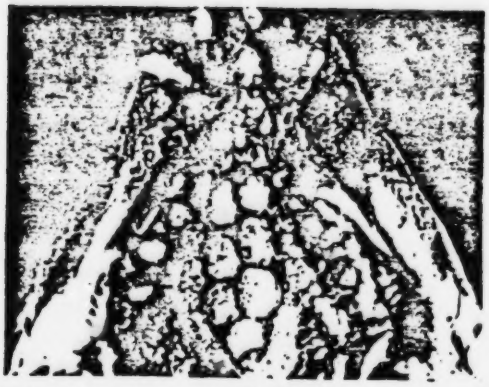

Fig.8: Anarrhichas lupus. Roof of the mouth cavity.

Fig.9 shows the floor of the mouth. The tongue is three-lobate and covered with diverging folds of the mucous membrane; in front of it on each side occur ca. ten domed, large crusher teeth on the medial surface of the lower jaw. Anteriorly they diverge slightly toward lateral against a group of two large conical teeth on each side. The obtusely rounded points of the latter teeth are slightly recurvate. The first mentioned domed teeth are covered with a whitish, tartarlike substance. Labial of these toward the margin of the jaw follows a wide zone covered with mucosa papillae; in front of the jaw is seen a distinct lip formation. The mucosa papillae curve anteriorly also around the large conical teeth and then, in the midline, push toward the back again as far as the tip of the tongue.

I made polished and sectioned median-sagittal preparations of the conical teeth from the symphysis area of the lower jaw as well as of the domed crushing-chewing teeth.

Fig.10 shows a polished median-sagittal section of a large, inner conical tooth, its tip bent lingually; in front and lingual of it the polished partial section of a smaller replacement tooth.

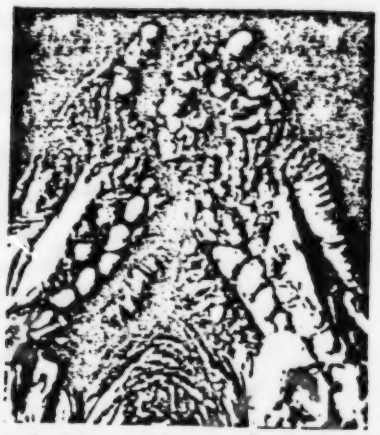

Fig.9: Anarrhichas lupus. Floor of mouth cavity.

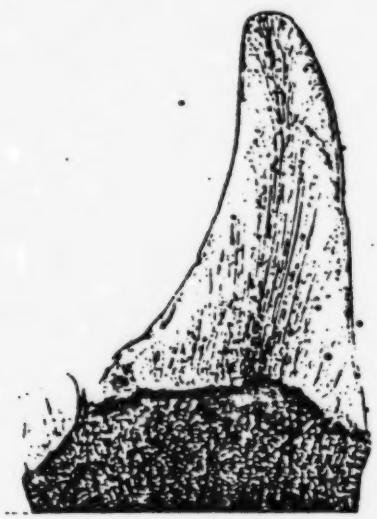

Fig.10: Anarrhichas lupus. Medial-most conical tooth of the lower jaw, polished sagittal section. Superficially on the right is seen the gray enamel layer.

Both teeth contain a very highly developed vasodentine which p.473 is remarkable on the one hand for its complexly ramified vascular tubules, and on the other hand for the complete or almost complete absence of a pulp cavity. The latter was the reason why Carl GEGENBAUR included a vague picture of such a wolffish tooth in the 2nd volume of his

comparative anatomy. The conical teeth are anchored to the lower jaw by means of a syndesmosis. From the interspaces of the spongiosa bone of the lower jaw, blood capillaries push up from below toward the tooth. They penetrate the tooth either directly - as at the periphery - or after passing through a flat pulp. The type of vascularization of this vasodentine differs therefore from that of the gadids; the average length of the vascular tubules and their ramification have also considerably increased (see fig.10). A further difference to the gadids (fig.1) is immediately apparent: the peripheral dentine zone, which is free of tubules of blood capillaries, is here extremely narrow. Its width only slightly exceeds the enamel layer which is very thin at the sides. In our specimen the latter together with the avascular dentine layer is ground off above the dome of the tooth.

Fig.11 shows the polished section of a dome-shaped lower jaw tooth. Its top is extensively worn down and in some areas no traces are left of the former thin enamel cap which is still recognizable at the sides. This tooth is also anchored to the lower jaw by a syndes- p.474
mosis with very short, usually calcified fiber bundles; its dentine is pervaded by a rich and greatly ramified system of blood capillaries. However, this capillary system originates here largely in the extremely flat but broad pulpal cavity where the entrance of a few vessels coming from the hollow spaces of the spongy bone can be occasionally observed. The avascular, peripheral dentine zone frequently does not reach the same width as the narrow enamel layer. I searched for dentinal tubules in the polished sections of both types of teeth but neither in the central nor in the peripheral dentine regions did I find the slightest trace of them in the rather finely granular, glassy dentinal matrix.

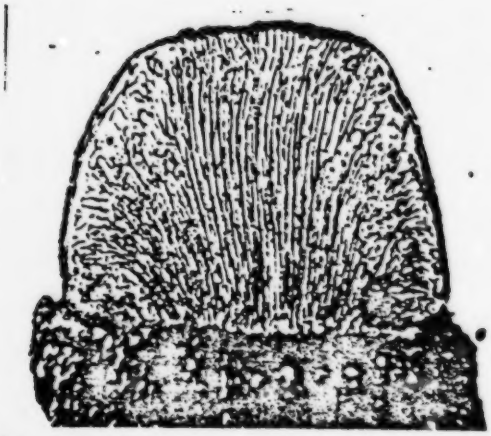

Fig.11: Anarrhichas lupus. Dome-shaped tooth of the medial lower jaw surface. Polished sagittal section.

I was able to establish here as well by means of decalcified sections of these teeth that the vascular tubules of this modified mantle dentine contained only fine blood capillaries but no pulp. Incidentally, these teeth also belong to KAMPSCHULTE's Type I.

Thus, the dentine in Anarrhichas is a much more highly organized vasodentine than that of Gadus morrhua and the other gadids. The hardness tests that I conducted once again with both tooth types impressively demonstrated the enormous hardness of these teeth. I want to express the presumption therefore, that the presence of vasodentine in certain bony fishes may be causally related with the special hardness of these teeth. However, the thought suggests itself to relate the conspicuous reduction in the size of the dental pulp in Anarrhichas, as opposed to the gadid and normal teleost teeth, with the vascular supply of the tooth. The experience with Gadus shows that while odontoblasts still play a part as dentine producers, they have largely lost their

role as carriers of the metabolism; consequently, the odontoblast-covered pulp more or less ceases to funtion in later life.

IV. The Vasodentine in Acanthurus nigrofuscus.

I had the opportunity to study, though in less detail, another representative of vasodentine teeth, Acanthurus nigrofuscus; its teeth were partially only 1 mm long, of peculiar palmate shape and brownish dark-green color.

KAMPSCHULTE based his third type of teleost teeth on the p.475
investigation of the pike tooth. Underneath its enamel cap, this tooth consists of peripheral mantle dentine and adjacent to it on the inside a zone of trabecular dentine, which all around projects deeply into the interior of the dental pulp. KAMPSCHULTE writes on p.372 that the teeth of the barracuda (Sphyraema) as well as those of the fossil acanthopterygian Saurocephalus belong to this Type III, and supposedly also the Acanthurus teeth. But on the basis of my investigations of Acanthurus nigrofuscus I became convinced that KAMPSCHULTE was mistaken in this assumption. Richard OWEN on Plate 44 of his odontography depicted premandibular teeth of Acanthurus nigricans the appearance of which left doubts indeed whether these teeth belonged to KAMPSCHULTE's Type III or represented vasodentine teeth.

Fig.12 shows the incisor-type tooth with its handlike broadened cutting edge which gives rise to 10-12 points of various length and shape. A narrow enamel layer is present in the cutting part; it gradually flattens and disappears toward the middle of the armlike basal part. An avascular dentine zone lies beneath it. It is partially

slightly wider than the enamel layer, but very narrow as compared to the vascularized zone. In some points of the cutting edge this zone apparently contains isolated dentinal tubules or traces of them. It is followed by vascular dentine. Its vascular network is supplied by vertically ascending blood capillaries from the armlike basal tooth part. Toward the cutting edge, the blood capillary network ends in individual, axial capillary loops in the marginal points. No evidence of dental pulp tissue was found in the capillary loops or in the thick, ascending branches of the basal part, so that in Acanthurus there does not exist a (continuous) dental pulp or vestigial pulp.

Fig.12: Acanthurus nigrofuscus. Incisor, lingual view, in transmitted light.

Evidence of the vasodentine character of the dentine of Acanthurus are:

1. The lack of dentinal tubules in general. Yet I had some doubts as to whether dentinal tubules or traces of them did or did not occur in the individual points of the cutting edge in the vicinity of the vascular tubules, as I mentioned above.

2. The presence of typical blood capillary tubules as seen in fig.12.

During the preparation of a polished section of one of these teeth I was impressed again by the extreme hardness displayed by these small-sized dental structures. This supports my assumption that the more highly developed the vasodentine, the harder are the teeth.

Summary and Conclusion.

Vasodentine is a form of dentine, the metabolism of which is directly initiated by blood capillaries. The latter usually come from the dental pulp, occasionally also - when the pulp is reduced - through hollow spaces of the underlying jaw bone into the dentine matrix. The original nutrition, i.e. by means of odontoblasts, is degenerated.

The extent of vascularization as well as that of the degeneration of the odontoblast processes varies. In Elena ARSUFFI's paper, photographs of the basal part of the molariform teeth of Sargus vulgaris, which here alone contain vasodentine, show the presence of dentinal tubules as well as vascular tubules given off by the pulp surface. - In gadids, RÖSE and I could only find vestiges of dentinal tubules in the peripheral parts of the vasodentine; in Anarrhichas I did not even find these. - There is an obvious necessity to carry out further studies of the vasodentine to broaden the knowledge about these interrelationships.

In Merlangus it has been ontogenetically established that odontoblasts with processes do take part in the dentine development. But the processes remain very short, and neither processes nor dentinal tubules are found in older dentine.

The dentine character of the vasodentine has therefore been established.

After some time, the central dentine zone becomes vascularized by a subsequent invasion of pulpal blood capillaries, which goes hand in hand with the gradual degeneration of the dental pulp; the peripheral dentine portion remains avascular. I was able to show in Anarrhichas and Acanthurus that this avascular zone may be very narrow. p.477

So far vasodentine was known only from gadids and recently also from the basal part of the molars in Sargus vulgaris. I was able to establish its presence in the highest form of development also in the acanthopterygians Anarrhichas and Acanthurus. However, I notice to my astonishment that the blennioid Blennius lacks vasodentine in the conical teeth of the lower jaw and has instead ordinary mantle dentine. This result further indicates the need for a continued search for vasodentine.

I was able to establish that vasodentine takes on the character of mantle dentine in JACOBSHAGEN's sense. It is a mantle dentine without basal cover plate. So far, all vasodentine teeth belong therefore to Type I of teleost teeth in KAMPSCHULTE's sense.

Finally, it has been stated that the development of the vasodentine presumably serves to increase the hardness of the dentine.

Bibliography.

Arsuffi, E.: Z. Zellforsch. 29 (1939). [1] Froehlich, H.: Bau und Befestigung des basalen Zahnendes im Kiefergebiß einiger Selachier. Diss., auszugsweise gedruckt. Leipzig 1923. [2] Gegenbaur, C.: Vergleichende Anatomie der Wirbeltiere 2. Leipzig 1901. [3] Giebel, C. G.: Odontographie. Leipzig 1855. — Hertwig, O.: Jena. Z. Naturw. 8 (1874). [4] Hessel, E.: Verteilung, Form und Struktur der Placoidschuppen der Selachier. Diss., auszugsweise gedruckt. Leipzig 1923. — Jacobshagen, E.: Verh. anat. Ges. Heidelberg 1923. — Kampschulte, Fr.: Z. mikrosk.-anat. Forsch. 46. 350 (1939). — Owen, R.: Odontography 1, 2. London 1840—1845. — Tomes, C. S.: Phil. Trans. Act. London 1878. — Quart. J. microsc. Sci. 41 (1899).

German Bibliographic Items.

1) Structure and anchorage of the basal tooth end in the jaw dentition of some selachians. Published excerpts of a dissertation.

2) Comparative vertebrate anatomy.

3) Odontography.

4) Distribution, shape and structure of selachian placoid scales. Published excerpts of a dissertation.